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(54) **Video signal processing for electronic watermarking**

(57) An image or sequence of images is watermarked without limiting the watermark signal. The watermarking apparatus includes a conventional DCT unit (108) and quantizer (110) for generating an array of quantized DCT coefficients. The array is watermarked (118) by masking the array to select certain ones of the DCT coefficients that are then replaced by zero values to form a masked array. The masked array is further processed by a watermark inserter(120) that replaces the zero valued coefficients with predefined watermark coefficients to form a watermarked array of DCT coefficients. e.g., a watermarked image. A decoder for decoding the bitstream thusly generated and for removing the embedded watermark is also taught.

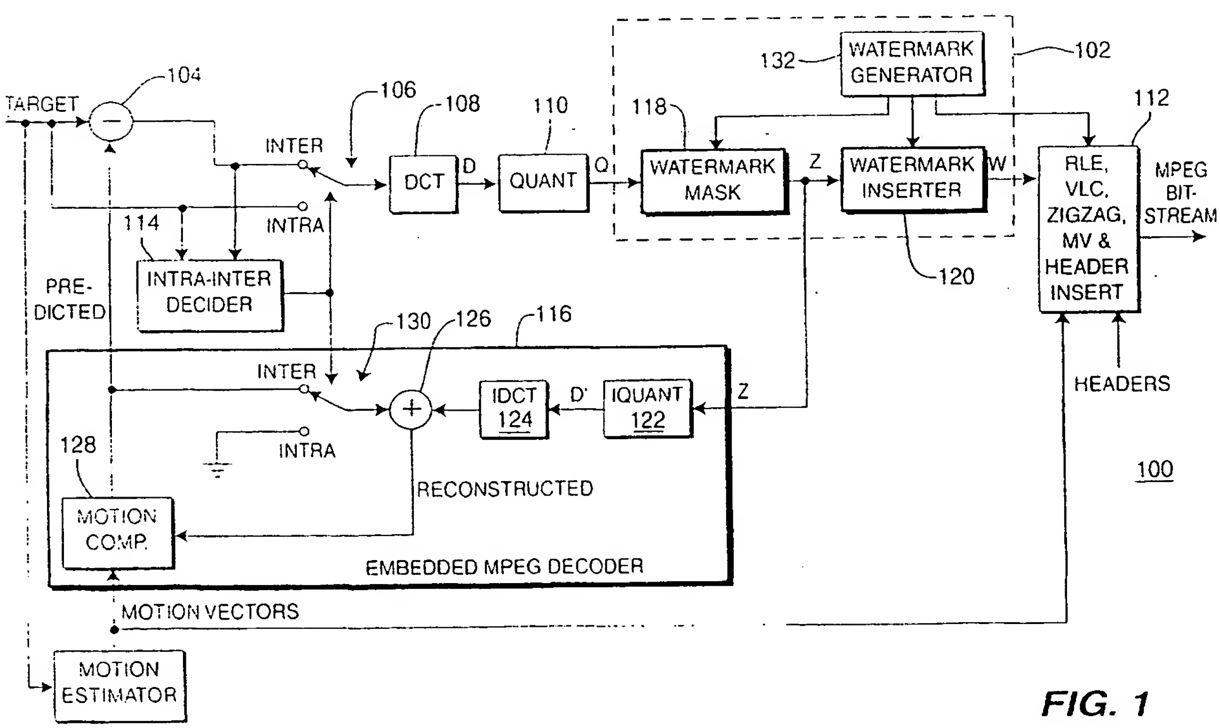

FIG. 1

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tized DCT coefficients and sets the value of each selected coefficient to zero A control signal. produced by the watermark generator. defines the particular coefficients that are to be masked The masked array of coefficients containing the "zeroed" coefficients is coupled to the embedded decoder 116 and used to produce a predicted image.

[0017] The masked block of DCT coefficients is coupled to the watermark inserter 120, where the zeroed coefficients are replaced with watermark coefficients. The watermark coefficients are supplied by the watermark control signal.

[0018] The watermarked block of DCT coefficients is then coupled to the output processor that combines the motion vectors and header information with the DCT coefficients and conventionally encodes the assemblage using zig-zag scanning. run-level coding (RLC) and variable length coding (VLC) to form an MPEG compliant bitstream. A control signal is provided to block 112 such certain watermark decoding information can be inserted into. for example. the user data fields of the bitstream. For example. when using a dynamically variable watermark. the synchronization information is inserted into the bitstream to enable a decoder to find and extract the watermark. Also. for pseudo randomly generated watermarks. a seed for decoding the watermark is inserted into the bitstream as, for example, picture layer user data. As such. the watermark related decoding information can be inserted as often as every picture. but need not be.

[0019] The masked block of coefficients is coupled to the embedded decoder 116. The embedded decoder 116 comprises an inverse quantizer 122. an inverse DCT unit 124 a summer 126. a inter-intra switch 128. and a motion compensation processor 128. This assemblage of components decodes the previously encoded block and motion compensates the block in a conventional manner Specifically, the masked block is inverse quantized and inverse DCT processed. As such, a block of reconstructed residuals is formed. These reconstructed residuals are nearly the same as the residuals produced at subtractor 104. but they lack the masked image information. The reconstructed residuals are summed with a predicted image within summer 126 and the summed reconstructed block is motion compensated within motion compensation processor 128 to form a predicted image. The inter-intra switch 130 operates in the same manner as switch 120 as well as also being under the control of the inter-intra decider 114. As such. the predicted image is used to form the reconstructed block and coupled through the switch 130 only when the residuals were originally encoded Otherwise. the output of the inverse DCT unit is a reconstructed target image that is coupled to the motion compensator without being added to a predicted image

[0020] It is important to note that the watermark mask 118 is within the "loop" that encodes and decodes the target image to form a predicted image. while the watermark inserter 120 is outside of that loop. By placing the watermark mask inside the loop. an authorized MPEG decoder will track the embedded decoder after the watermark is removed

[0021] The watermark inserter 120 is outside the loop to ensure that the watermarked values are "branded" into the bitstream. Note that the watermarked DCT coefficients are modified at the last possible encoding stage and that no further "lossy" processing occurs after the watermark coefficients are inserted into the masked array of DCT coefficients. All the processes that are performed by the output processor are lossless, e.g., zig-zag scanning, VLC and RLC.

[0022] Using the embodiments of watermarking apparatus according to the present invention. an unauthorized MPEG decoder will not track the embedded decoder because an unauthorized decoder will not be able to remove the watermark from the decoded block. As such, the output images from an unauthorized decoder will contain periodically fluctuating noise whose visibility is controlled by the value of the watermarked coefficients. A decoder that can be used to remove a watermark embedded in the manner discussed above, is disclosed with respect to FIG. 5 below.

[0023] FIG. 2 depicts a block diagram of the process used to embed the watermark into an image and FIGS. 3, 4, and 5 graphically depict the array of DCT coefficients as it is processed by the present embodiment. To best understand the process the reader should simultaneously refer to FIGS. 2, 3, 4. and 5.

[0024] Specifically. the illustrative watermarking routine 200 according to the invention begins. at step 202, with an input image (e.g.. the residual image). At step 204. the input image is converted to the frequency domain using a discrete cosine transformation of the image content and then quantizing the DCT coefficients. FIG. 3 graphically depicts an 8x8 block or array 300 of quantized DCT coefficients The watermark mask is applied at step 206 to select certain ones of the DCT coefficients. At step 208, the selected coefficients are "zeroed", i.e.. assigned a zero value. FIG. 4 graphically depicts the block 300 of FIG. 2 after having a watermarking mask applied to the block and the selected DCT coefficients 400 set to a zero value. At step 210, the routine produces the masked array as an output. As described above. in an MPEG decoder application. the masked array can be used by an embedded encoder to produce a predicted image.

[0025] At step 212, the routine 200 replaces the selectively zeroed coefficients with watermark values (i.e.. quantized DCT coefficients derived from a watermark image) Care must be taken in selecting DCT coefficients for replacement. If the watermark is to have low visibility, then it is critical that relatively small watermark DCT values e g.. -1. 0. +1 be inserted into the locations carrying the highest frequency coefficients of the DCT. Such highest frequency locations are generally in the lower right hand corner of the DCT block Masking these

coefficients will cause a low-level "cheesecloth"-like appearance in the reconstructed values. However. such an effect does not generally produce visible artifacts in the decoded image sequence To further reduce the visibility of the cheesecloth effect. the watermark DCT values that are inserted can be reversed in polarity in co-sited macroblocks from frame-to-frame. As such. the average luminance deviation is zero and therefore less visible. If the watermark is to have high visibility, large watermark DCT values should be used. FIG. 5 graphically depicts the array 300 after watermark DCT coefficients 500 have been inserted into the masked locations in the array. At step 214, the routine outputs the watermarked array of DCT coefficients.

[0026] The replaced DCT coefficients will affect the bit count associated with each block in the picture, i.e.. each block in a picture that is encoded is allocated a certain number of bits that are used to encode the block and the addition of the watermark values will generally increase that bit count. In some cases, the addition of a watermark, may decrease the bit count, but in most cases (i.e., where the high frequency DCT coefficients would have otherwise been zero values), the bit count will be increased. However. careful selection of the watermark coefficients can minimize the additional bit count. For example. it is more efficient to code coefficients with magnitude 0 or 1 than it is to code values with greater magnitude. Thus. low magnitudes should be used as watermark coefficients. Additionally, the rate control technique (i.e.. the algorithm that actually controls the coding rate and quantization scale for the DCT coefficients) can be modified on either a local or global basis to account for the slight increase in bit rate that adding watermark coefficients will require.

[0027] The actual watermark values may be deterministically. pseudo-randomly or cryptographically generated within the watermark generator (132 of FIG. 1). For instance. the generator 132 converts a trademark (e.g.. XYZ) or some other identifying word or image into a binary (ASCII) equivalent. The binary values. for example. are then used to replace the quantized coefficient Q(7,7) of FIG. 2 with a 1 or 0 in successive blocks that are processed by the encoder. In this manner, only one coefficient in each array of coefficients is replaced.

[0028] Alternatively. a pseudo-random sequence generator could generate a pseudo-random value. normalize the value and replace Q(7.7) with a 0 whenever the normalized value is in the range 0 to 0.5, and replace Q(7.7) with 1 whenever the normalized value is in the range 0.5 to 1. The type of watermark that is used (deterministic or pseudo-random) can be transmitted to the receiving decoder using the user data field within the MPEG transport stream. When using a pseudo-randomly generated code. the user data can also be used to transmit a "seed" for the pseudo-random code such that the decoder can easily extract the watermark. Using the user data in this manner. allows the encoder that inserts the watermark to change the watermark code while still allowing the authorized decoder to automatically remove the new watermark.

[0029] Once the watermark is inserted into an image in the manner described above. an unauthorized decoder (e.g., standard MPEG) processes the watermark as if it were the coded image Depending upon the watermark coefficients, the watermark will either be visible or invisible in the decoded images. In some cases, it is desirable to have a highly visible watermark that appears in any images that were decoded using an unauthorized decoder. However. such a visible watermark would require removal from images decoded by an authorized decoder.

[0030] FIG. 6 depicts a block diagram of a block-based image decoder (e.g., an MPEG decoder) for decoding a bitstream generated by the encoder of FIG. 1 and simultaneously removing a watermark from the decoded image sequence. The decoder 600 comprises an input processor 602. a watermark remover/comparator 604, and a conventional decoder 606. The input processor 602 processes the MPEG-compliant bitstream by variable length decoding, run-length decoding, inverse zig-zag scanning, and removing the header to produce a block (array) of quantized DCT coefficients containing watermark information. The picture layer user data contains information regarding the manner in which the DCT block has been modified to include the watermark, i.e., the information details which locations contain watermark data. From the user data, the input processor 602 produces a control signal that is coupled to the watermark remover/comparator 604. This control signal provides the locations of the coefficients that carry the watermark values. To verify the authenticity of the watermark, the watermark remover/comparator extracts the watermark values from the block and the extracted watermark coefficients are compared against a stored reference (or a reference that is pseudo-randomly generated from a seed transmitted from the encoder to the decoder). If a match occurs. the authenticity of the watermark is confirmed and an authentication signal is produced. If no match is found. then the watermark was not inserted by an authorized encoder. If a match occurs, the watermark remover/comparator then "zeroes" the watermark value in each of those locations to produce the block Z (also depicted in FIG. 4). However, without a match. the watermark remover/comparator will not zero the watermark values and. as such. any reconstructed images will be distorted by the watermark values.

[0031] To complete decoding of the bitstream, the MPEG decoder 606 comprises an inverse quantizer 608 an inverse DCT unit 610. a summer 612. a inter-intra switch 614 and a motion compensator 616. The motion vectors and the intra/inter decisions associated with each block are extracted from the bitstream by the input processor 602 and coupled to the MPEG decoder 606. The inverse quantizer 606 and inverse DCT unit 610 operate upon block Z to inverse quantize and inverse DCT process the block to form a block of pixels

The summer 612 sums the pixels with a predicted block of pixels to form a reconstructed image. If the block was intra-coded in the encoder then a predicted block is not applied to the summer 612 i.e.. the switch 614 is switched to the intra terminal which is grounded. The reconstructed image is produced at the decoder output and also coupled to the motion compensator to be motion compensated to form a predicted block.

[0032] Although various embodiments which incorporate the teachings of the present invention have been shown and described in detail herein, those skilled in the art can readily devise many other varied embodiments that still incorporate these teachings.

Claims

1. An image encoder for inserting a watermark into an image containing a plurality of pixels. where the pixels are encoded using discrete cosine transform (DCT) coefficients, comprising:

   a watermark mask for masking an array of DCT coefficients representing said image and setting select ones of said DCT coefficients in said array to a zero value: and
   a watermark inserter, coupled to said watermark mask, for inserting watermark values into locations in said DCT coefficient array where said DCT coefficients were masked and set to a zero value.

2. A DCT based image encoder for inserting a watermark into an image containing a plurality ofpixels. where the pixels are encoded using discrete cosine transform (DCT) coefficients, comprising:

   a watermark mask for selecting certain ones of said DCT coefficients representing said image and changing the value of the selected DCT coefficients to zero to form a masked array of DCT coefficients:
   an image decoder. coupled to said watermark mask, for generating a predicted image from said masked array of DCT coefficients:
   a watermark inserter, coupled to said watermark mask, for replacing the selected DCT coefficients with watermark values to produce a watermarked array of DCT coefficients:
   an output processor. coupled to said watermark inserter. for losslessly coding said watermarked array of DCT coefficients to form a bitstream.

3. The apparatus of claim 1 or 2 further comprising a watermark generator for producing said watermark coefficients as quantized DCT coefficients of a predefined character string.

4. The apparatus of claim 1 or 2 further comprising a watermark generator for producing said watermark values are pseudo-randomly generated.

5. The apparatus of claim 4 wherein said watermark generator is coupled to said output processor and supplies said output processor with certain information useful in decoding said watermark values, where the output processor inserts the certain information into said bitstream.

6. The apparatus of claim 5 wherein said certain information is a seed for decoding said pseudo-randomly generated watermark values.

7. A method of inserting a watermark into an image containing a plurality of pixels, where the pixels are encoded using discrete cosine transform (DCT) coefficients, comprising the steps of:

   masking an array of DCT coefficients representing said image and setting select ones of said DCT coefficients in said array to a zero value: and
   inserting watermark values into locations in said DCT coefficient array where said DCT coefficients were masked and set to a zero value.

8. A method of extracting a watermark from a bitstream comprising the steps of:

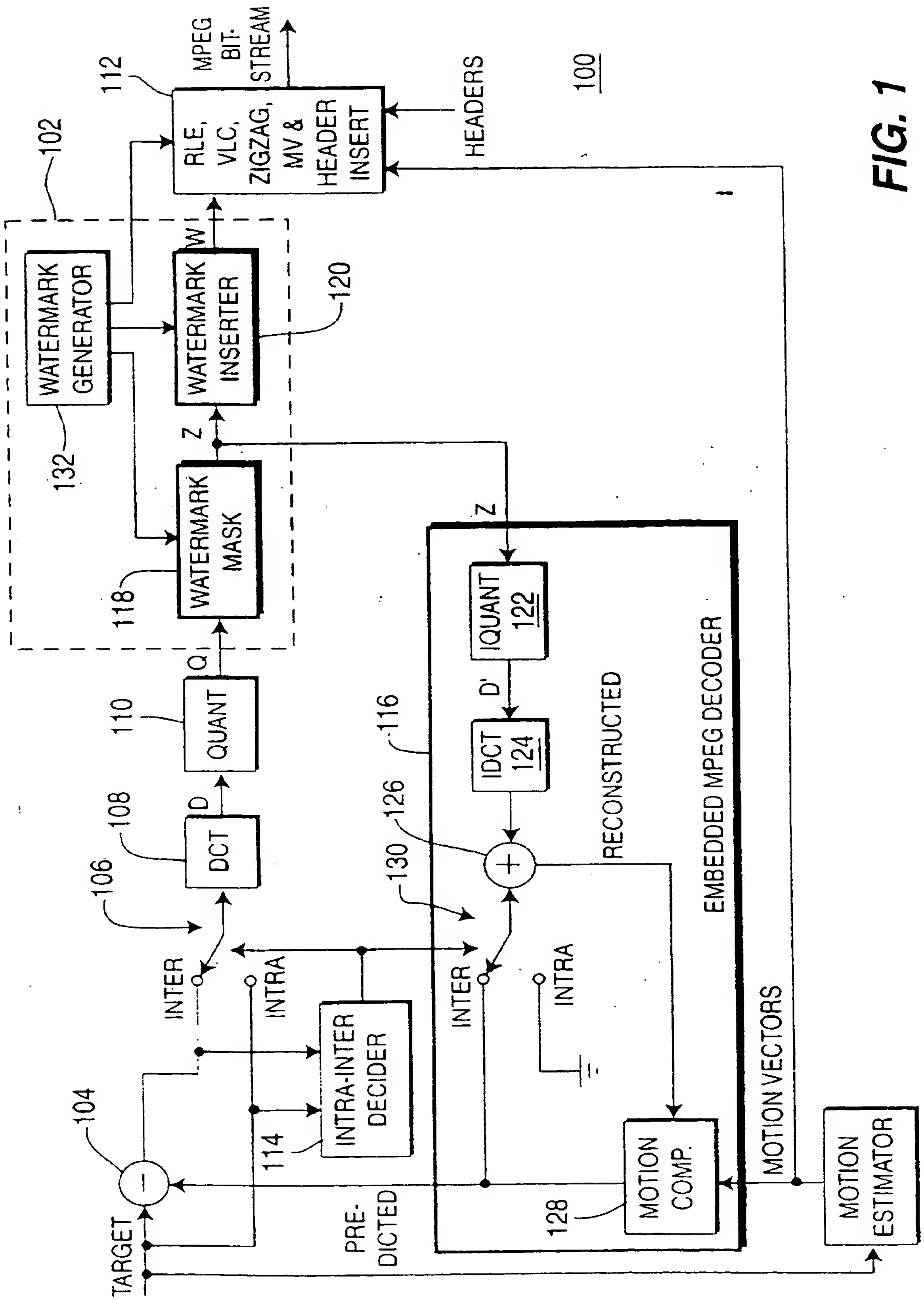
   extracting, from the bitstream, DCT coefficients that contain watermark values:
   comparing the watermark values to reference watermark values:
   producing an authentication signal if the watermark values match the reference watermark values:
   if said authentication signal is produced, setting said watermark values in said DCT coefficients of said bitstream to zero to remove the watermark from the DCT coefficients in the bitstream, whereby an image is decoded without the appearance of a watermark.

9. The method of claim 8 further comprising the step of recalling said reference watermark values from memory.

10. The method of claim 8 further comprising the step of:

    decoding information within said bitstream to produce said reference watermark values.

11. The method of claim 10 wherein said information is a seed for a pseudorandom code that forms the basis for the reference watermark values



TARGET
104
PRE-
DICTED
INTER
INTRA
106
DCT
108
D
QUANT
110
Q
114
INTRA-INTER
DECIDER
WATERMARK
MASK
118
Z
WATERMARK
GENERATOR
132
WATERMARK
INSERTER
120
W
102
RLE,
VLC,
ZIGZAG,
MV &
HEADER
INSERT
112
MPEG
BIT-
STREAM
HEADERS
100
Z
IQUANT
122
D'
IDCT
124
116
126
130
INTER
INTRA
RECONSTRUCTED
EMBEDDED MPEG DECODER
MOTION
COMP.
128
MOTION VECTORS
MOTION
ESTIMATOR

FIG. 1

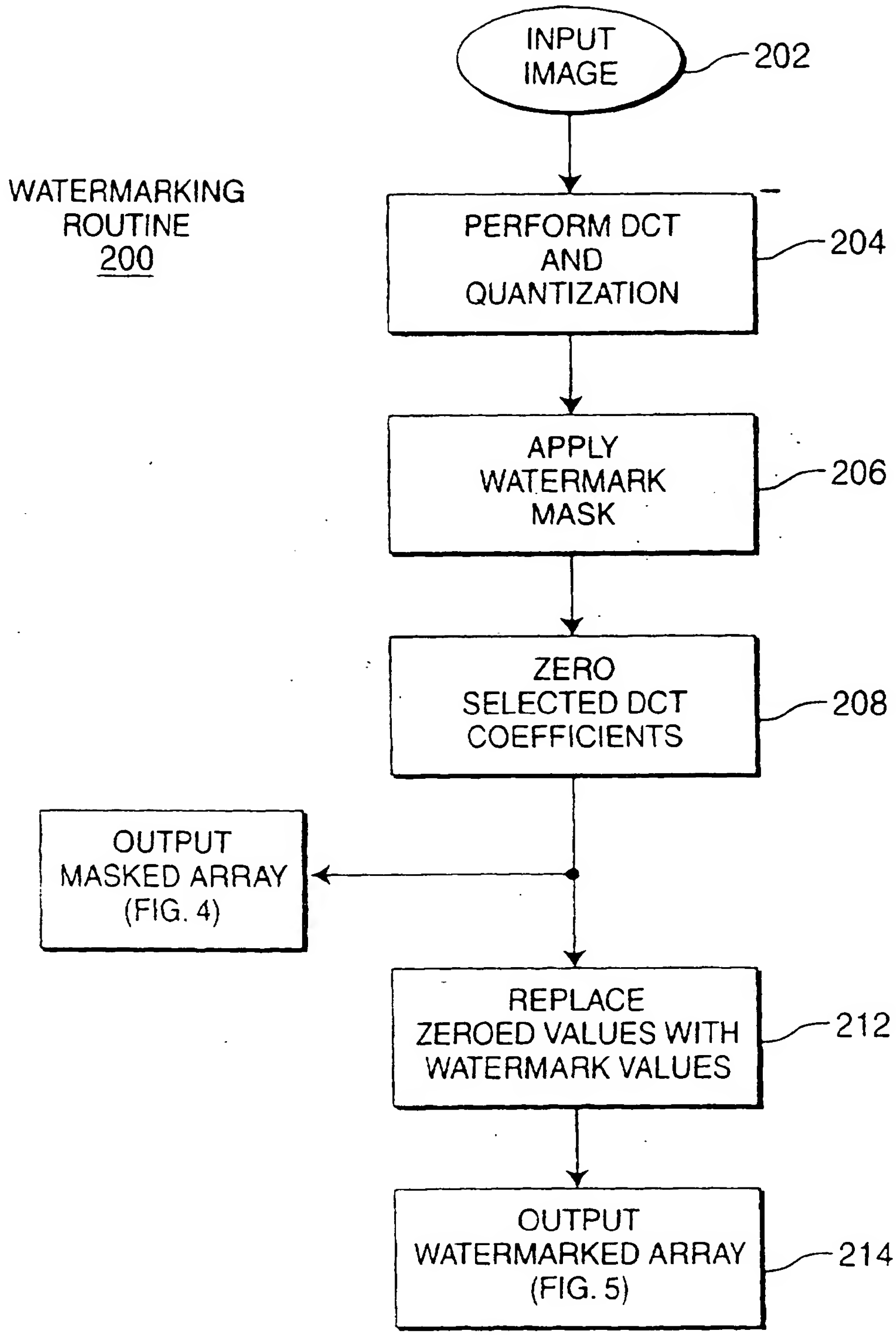

INPUT IMAGE
202
WATERMARKING ROUTINE 200
PERFORM DCT AND QUANTIZATION
204
APPLY WATERMARK MASK
206
ZERO SELECTED DCT COEFFICIENTS
208
OUTPUT MASKED ARRAY (FIG. 4)
REPLACE ZEROED VALUES WITH WATERMARK VALUES
212
OUTPUT WATERMARKED ARRAY (FIG. 5)
214

FIG. 2

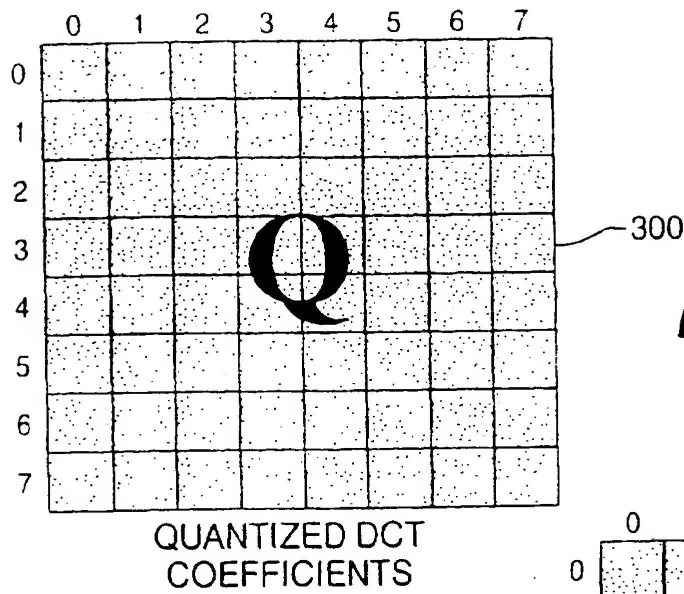


FIG. 3

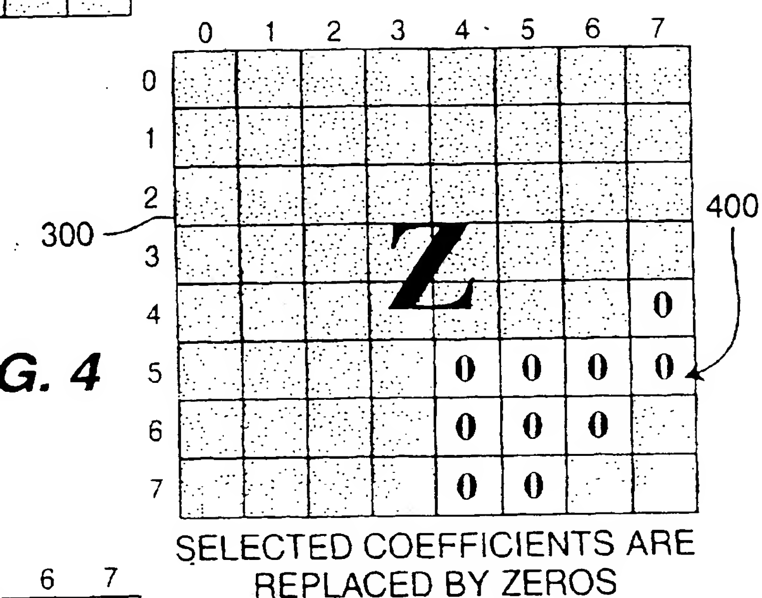


FIG. 4

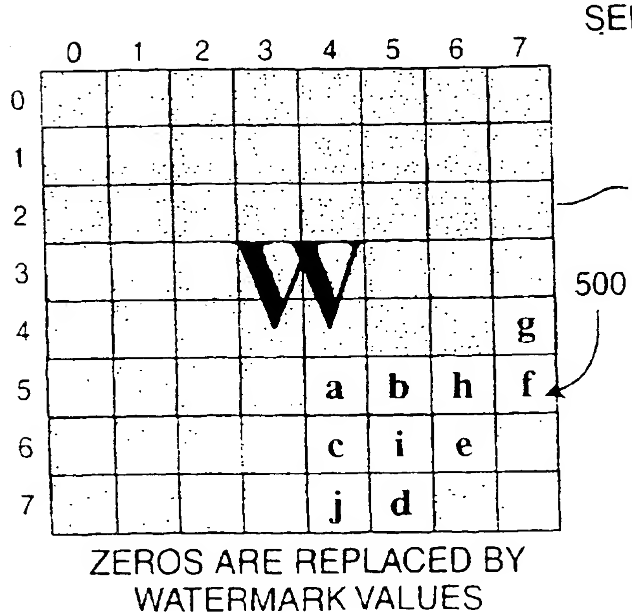


FIG. 5

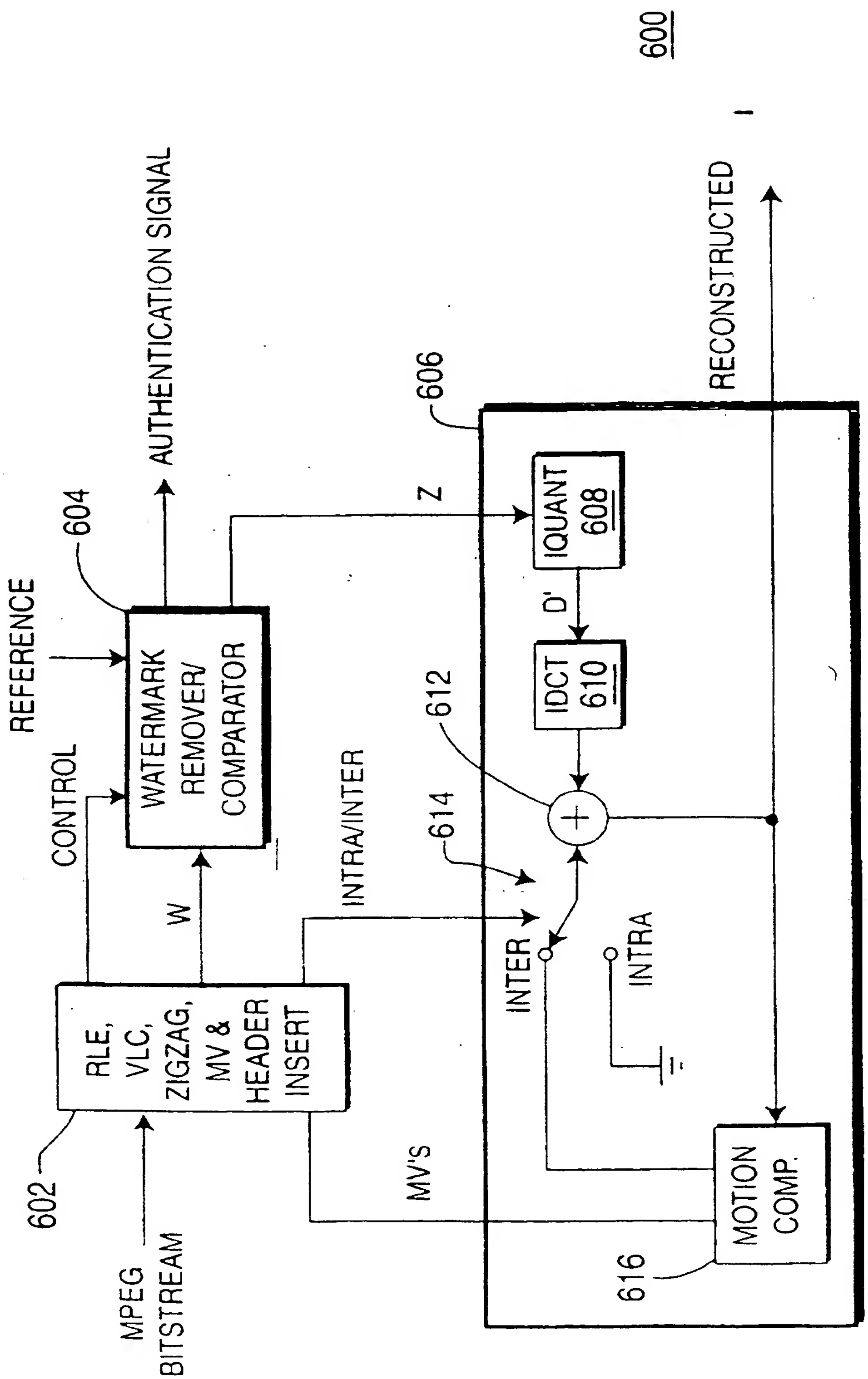

600
MPEG BITSTREAM
602
RLE, VLC, ZIGZAG, MV & HEADER INSERT
CONTROL
W
REFERENCE
604
WATERMARK REMOVER/ COMPARATOR
AUTHENTICATION SIGNAL
Z
INTRA/INTER
MV'S
606
IQUANT 608
D'
IDCT 610
612
614
INTER
INTRA
616
MOTION COMP.
RECONSTRUCTED

FIG. 6

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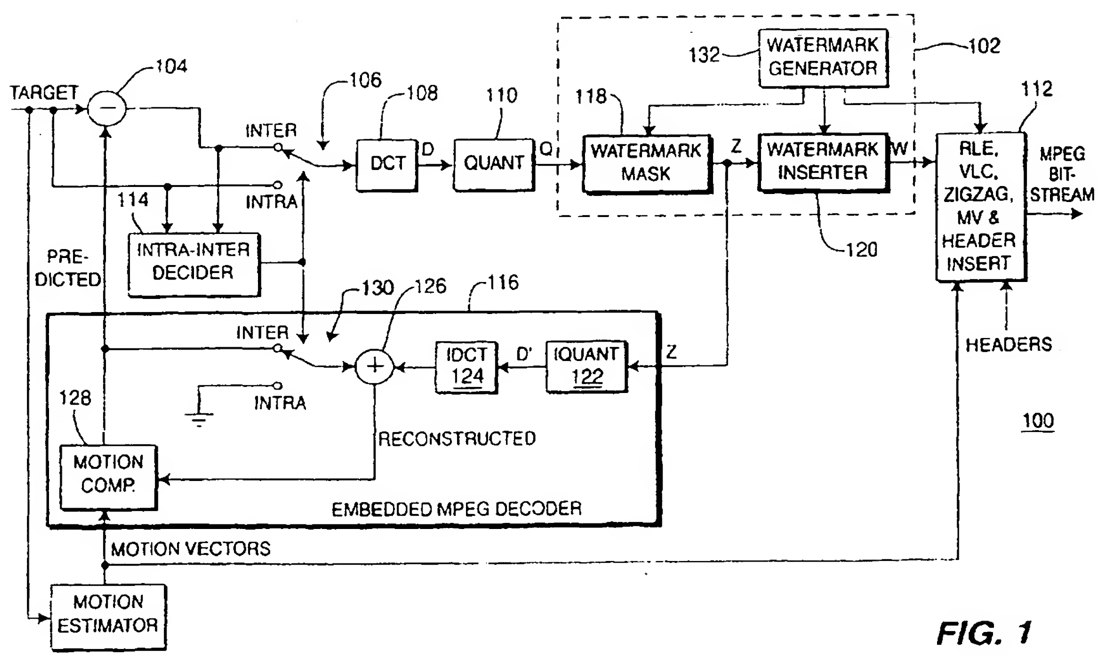

FIG. 1

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EUROPEAN SEARCH REPORT

Application Number
EP 98 31 0313

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X A	EP 0 766 468 A (NIPPON ELECTRIC CO) 2 April 1997 (1997-04-02) * page 5, column 7, line 52 - page 6, column 9, line 6 * * page 7, column 11, line 4 - page 9, column 15, line 4 * ---	1,3,4,7,8 5,6,9-11	H04N7/26 H04N7/50
X A	ZHAO J ET AL: "EMBEDDING ROBUST LABELS INTO IMAGES FOR COPYRIGHT PROTECTION" PROCEEDINGS OF THE KNOWRIGHT. CONFERENCE. PROCEEDINGS OF THE INTERNATIONAL CONGRESS ON INTELECTUAL PROPERTY RIGHTS FOR SPECIALIZED INFORMATION, KNOWLEGDE AND NEW TECHNOLOGY, 21 August 1995 (1995-08-21), pages 242-251, XP002050067 * paragraph '0002! * * paragraph '03.1! * ---	1,3,4,7 5,6	
X A	BARNI M ; BARTOLINI F ; CAPPELLINI V ; PIVA A : "Robust watermarking of still images for copyright protection" 13TH INTERNATIONAL CONFERENCE ON DIGITAL SIGNAL PROCESSING . 4 July 1997 (1997-07-04), pages 499-502, XP002118117 Santorini, Greece * paragraph '0003! * * paragraph '03.1! * ---	1,7,8 2,4-6, 9-11	**TECHNICAL FIELDS SEARCHED (Int.Cl.6)** H04N
A	EP 0 562 787 A (CANON KK) 29 September 1993 (1993-09-29) * page 5, column 7, line 55 - column 8, line 49 * ---	1,7	
A	WO 96 41468 A (MACROVISION CORP) 19 December 1996 (1996-12-19) * page 11, line 7 - page 12, line 21 * -----	8-11	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	18 October 1999	Marie-Julie, J-M

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0766468 A	02-04-1997	AU 701639 B	04-02-1999
		AU 6584096 A	10-04-1997
		CA 2184949 A	29-03-1997
		JP 9191394 A	22-07-1997
		US 5930369 A	27-07-1999
EP 0562787 A	29-09-1993	JP 6078287 A	18-03-1994
		US 5592302 A	07-01-1997
WO 9641468 A	19-12-1996	US 5659613 A	19-08-1997
		AU 700013 B	17-12-1998
		AU 5869396 A	30-12-1996
		CA 2220845 A	19-12-1996
		EP 0830783 A	25-03-1998
		JP 11507160 T	22-06-1999

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